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Prediction of Curve Progression in Idiopathic Scoliosis

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Document Version

Publisher's PDF, also known as Version of record

Publication date:

2004

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Cheung, J. (2004). Prediction of Curve Progression in Idiopathic Scoliosis: A radiographical and electromyographical study. Groningen: s.n.

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In chapter 1, the reasons for establishing this thesis are described. Despite a number of studies, the natural history of idiopathic scoliosis and the risk of curve progression remain unknown. Knowledge of factors that influence the prognosis in idiopathic scoliosis is essential in evaluating these patients with scoliosis and in planning an adequate and rational treatment program. This thesis focuses on identifying factors related to progression of the scoliotic curve and on using these factors to predict which curve will progress and which will not. The chapter ends by stating the aim of this thesis.

Chapter 2 is an introduction to the anatomy of the spine and the general characteristics of scoliosis in which aspects such as classification, prevalence, etiology, natural history, screening, history and physical examination, radiographic evaluation and treatment of idiopathic adolescent scoliosis are described.

Idiopathic scoliosis is a complicated three-dimensional deformity (3-D) of the trunk, characterized by both lateral curvature of the spine and vertebral rotation. It is the most common form of lateral deviation of the spine and is classified in three groups according to the age at the time of diagnosis: infantile (0-3 years); juvenile (4-10 years); and adolescent (10 years to skeletal maturity). Another classification is made into early onset (before the age of 5) and late onset. Idiopathic scoliosis affects approximately 2-3% of the at-risk population, age 10-16 years. Girls more commonly need treatment than boys for the more severe curves. As the name implies, the etiology of idiopathic scoliosis remains unknown; it is now generally regarded as multifactorial with genetic factors playing an important role. The natural history of idiopathic scoliosis does not always follow the same course. Some cases are progressive while others remain stable or disappear spontaneously. Progression often occurs during periods of significant growth. The diagnosis of adolescent idiopathic scoliosis is reached primarily by exclusion. Screening, history and physical examination are intended to exclude secondary causes for spinal deformity. The characteristic sign of the scoliosis is the rib hump, which occurs at the convex side of the curvature as expression of truncal rotation. Idiopathic scoliosis is typically evaluated using standard radiographs of the spine with the Cobb angle method to measure the severity of the scoliotic curve. Nowadays newer digital techniques are expected to give a greater amount of information on the complex scoliotic deformity and to significantly reduce radiation exposure. Treatment of scoliosis is non-operative or operative options. Non-operative treatment could consist of observation, postural exercises and bracing. The gold standard for operative treatment of idiopathic adolescent scoliosis has been spinal fusion accompanied by curve correction and stabilization with instrumentation.

Chapter 3 describes a newly developed computer-assisted method for measuring scoliotic spines on digital radiographic images and the reliability of the measurements on these digital

images. Measurements obtained from radiographs play a crucial role in clinical decision-making concerning the mechanisms of progression in patients with scoliosis. Therefore, the use of an accurate and reliable measuring method is important for a clear evaluation of the complex 3-D scoliotic curve. The new computer-assisted measurement method in this study uses digital reconstruction images of the spine. The reliability of the new method was studied from the measurements performed by five observers on 30 frontal and 10 lateral scoliotic digital reconstruction images. Each image was measured on 3 separate occasions through positioning of anatomical landmarks on the vertebrae and pedices and by drawing lines with a cursor on a computer screen.

The computer then calculated a number of geometrical variables, which are derived from all 3-D planes, out of the landmarks and lines after scale calibration. Comparing to literature, the results of this study demonstrated that the reliability of our new method on digital reconstruction images is better than measurements on conventional roentgenograms. The presented method is therefore considered more accurate for research of the development of the scoliotic spine and more adequate for clinical management of scoliosis.

Chapter 4 presents a simple neurophysiologic experiment through laserline projection to determine the perception of body posture in children with scoliosis. The frequency with which scoliosis is found in many different neurologic syndromes has led to repeated attempts to find a neuromuscular cause for idiopathic scoliosis. Possible causes may be disturbances in the equilibrium system in the brain stem and the related postural control system. Apart from electromyography no other neurophysiologic approach of prognostic value for idiopathic scoliosis is reported in literature. Therefore, we introduced a simple neurophysiologic prognosticum to evaluate spatial orientation in children with or without idiopathic scoliosis: 89 children with idiopathic scoliosis, 50 children with congenital scoliosis and 45 healthy controls without scoliosis were evaluated. The children were instructed to adjust a laserline projection to the direction of gravity in vertical and in horizontal projections in a dark environment. The three groups fulfilled the vertical and horizontal adjustments within the same accuracy. No relation was found to age, sex or severity of scoliotic deformity. It was concluded that perception of postural control in idiopathic scoliosis is not altered and that children with a spinal asymmetry of an idiopathic nature cannot be distinguished from those of non-idiopathic nature on the basis of this experiment with the laserline projection.

Chapter 5 evaluates the electromyographic (EMG) activity of the paraspinal muscles to determine its relationship to progression of the scoliotic curve. In this chapter it could be asserted that the EMG activity of the paraspinal muscles plays a significant role in the progression of scoliosis. The idea was that the extent of paraspinal muscle activity would reveal differences in muscle involvement in idiopathic scoliosis that may correlate to the

progression of the scoliotic curve. Twenty-three patients with idiopathic scoliosis were divided into two groups according to the progression of the scoliotic curve. The EMG activity on both sides of the spine was measured during a set of different test conditions using bipolar surface electrodes at the apex and two end vertebrae of the scoliotic curve. The EMG ratio involving measurements of the EMG activity on the convex and concave side of the scoliotic curve was used to evaluate the paraspinal muscles. Higher EMG ratios at the apex of the scoliotic curve were found in both groups and the groups did show quite different patterns of EMG activity ratios during the test conditions. The most interesting finding was that children with progression of the curve did also show EMG ratio differences at the lower end vertebra of the curve. The results show that there is a relationship between EMG activity at the lower end vertebra of the curve and progression of the curve in idiopathic scoliosis. However, it should be kept in mind that overlap in the EMG ranges made differentiation difficult for prediction of the progression of the individual scoliosis patient. Summarized, EMG of the paraspinal muscles might be of value for prediction of progression in idiopathic scoliosis.

Chapter 6 describes the correlation between the growth velocity of the spine and the EMG activity of the paraspinal muscles in order to establish more detailed insight in its relationship to progression of the scoliotic deformity. Thirty patients were prospectively evaluated with protocolled radiographs and EMG measures. Spinal growth velocity was measured as the length differences of the scoliotic spine between two consecutive radiographs. All periods between two consecutive visits were scored as progressive or non-progressive. Based on the results, we constructed a nomogram with the spinal growth velocity and EMG ratio to predict the risk of curve progression. In the presented nomogram a spinal growth velocity of >15 mm per year combined with an EMG ratio of >2 gives an 89 % probability of progression of the scoliotic deformity. Growth velocities below 8 mm per year never result in progression. The study has established a clear association between both the spinal growth velocity and EMG ratio of the paraspinal muscles and progression of the scoliotic deformity. These findings may be valuable as a predictive factor for early identification of individuals with AIS who are at greater risk for progression.

Chapter 7 focusses on measurements of various geometrical parameters and the paraspinal activity of the scoliotic curve. An understanding of the natural history of idiopathic scoliosis is important to guide a surgeon's treatment protocol. The purpose of this longitudinal study was to elucidate the natural history and behaviour of the scoliotic curve and to assess which factors can be taken into account for predicting curve behaviour. Radiographical and electromyographical data collected throughout the natural history of the scoliosis indicate that a high spinal growth velocity and an enhanced paraspinal activity ratio at the lower end

vertebra are prominent risk factors. The asymmetric muscle activity is associated with enhanced axial rotation, which on its turn is associated with increasing Cobb angle and diminishing kyphosis. The combination of these parameters reflect physiological and biomechanical 3-D views on the natural history of the progression in idiopathic scoliosis.

Chapter 8 is the final part of this dissertation in which the main findings and clinical implications of the studies are discussed and suggestions for future research are given. The main conclusion of this thesis is that the combination of the parameters spinal growth velocity and paraspinal activity ratio at the lower end vertebra, leading to an enhanced axial rotation and diminished kyphosis provide the best basis for evaluation of curve progression in patients with idiopathic scoliosis. The results of this thesis provide clinical knowledge that could be valuable in decision-making as regards planning an adequate treatment of scoliosis.